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REVIEW OF PANEL DISCUSSIONS AND CONCLUSIONS REACHED RELATIVE TO SEAL DURABILITY IN INSULATING GLASS UNITS

This report is to provide a summary and narrative of the discussions and conclusions that were reached by a panel of individuals associated with and experienced in the insulating glass field. The discussions occurred on June 27, 2001 in a meeting in Cincinnati by a panel of experts invited by the Department of Energy (DOE) to discuss the durability of seals in insulating glass units (IGU). The following personnel were invited to the panel meeting in Cincinnati:

Chris Barry, Pilkington N. America, Inc.
Al Czanderna (Chair) NREL Consultant
Hakim Elmahdy, IRC/NRC of Canada
Randi Ernst, FDR Designs, Inc.
Jim Fairman, Aspen Research Corporation
Werner Lichtenberger, TruSeal Technologies
Bill Lingnell, *LINGNELL CONSULTING SERVICES*
Andre Piers, TNO Institute of Applied Physics, The Netherlands, also Participant in IEA Task 27
Bob Spindler, Cardinal IG
Sven Svenson, IEA*
Carl Wagus, American Architectural Manufacturers Association, (AAMA)
Sam Taylor, ex officio, DOE
"Corresponding Member," Bipin Shah, NFRC Staff
"Corresponding Member," Dariush Arasteh, LBNL*

* Did not attend

In addition to those listed above Mr. Jim Krahn, President NFRC, Christian Koehler, LBNL, Jim Larson and Brian Crooks, Cardinal IG and Ren Anderson, NREL, also attended part of the meeting.

The basis for the discussions was focused from a report provided by Dr. Al Czanderna dated December 4, 2000 titled "Seal Durability in Insulating Glass Units: Summary of Technical Issues and Recommendations to the Department of Energy". The panel was asked to address the major issues documented in the report, address priorities, and provide guidance on how to accomplish the objectives set forth by each item. The information provided is based on discussions, recommendations, and conclusions by the panel to provide DOE with information related to funding in an effort to improve IGU seal durability providing substantial energy savings in US commercial and residential buildings.

Dr. Czanderna selected and convened the panel of experts on seal durability of insulating glass as recommended in the summary of recommendations (Item A) of a previously published summary of recommendations A through M. Item A was the convening of the panel, which was the meeting that was approved by DOE to be held in Cincinnati on June 27, 2001. Items B through M on the summary of recommendations were thoroughly reviewed by the panel in the daylong session in Cincinnati. The outcome of each item was discussed in detail and prioritized with all panel members in participation. Recommendations from the panel were sorted in reference to the highest priorities by the group during the meeting and are discussed in this report. The priorities of the Items B through M were established as "high", "intermediate", and "low". All items referenced in the initial report were deemed to be worthy of support by DOE, however, it was the panel's objective and charge to establish priorities to detail the results of this meeting.

The meeting convened at 8:10 a.m. in Cincinnati at the Crowne Plaza Hotel. Dr. Czanderna introduced the panel members, and Sam Taylor of DOE offered opening remarks relating to the history and road map of energy efficient products with durability being the priority that was established two years ago. Mention was made of the research and testing requirements to predict performance for long term durability on advanced coatings and other issues important to insulating glass performance, such as gas retention and work being done by researchers on review of gas retention capabilities. Mention was made by members of the panel regarding seal durability importance and gas retention along with discussions of the importance toward predicting the service lifetime of an IGU.

The following is a discussion of the 12 recommendations (Items B through M) that were presented. The recommendations are listed in the priority ranking established by the group to give a general overall ranking of the 12 recommendations. The highest priority, R and D is listed first, progresses to the lowest priority. They are grouped in three areas, i.e., which has four items; intermediate, which has three

items; and lowest, which has four items. The remaining Item M was designated as a subset of other items in the list.

HIGHEST PRIORITY

1. (Item B) Support the concept to fund R&D to -
a. develop new testing protocols for IG use and system affects that result in failures/performance that can be correlated with failures/performance encountered from in-service use

b. purchase two chambers for evaluating the merits of P1 and P2 testing and the new newly devised protocols

c. lead a task for consolidating all the variations in accelerated and real time testing into one protocol, and have it balloted to be an ASTM Standard

d. identify other related activities

There was much discussion by the panel on issues occurring in the testing protocols of P1 and P2 test programs along with using the new ASTM Standard being proposed for IGUs. Information on desiccant loading and lifetime of units established in Europe based on the prEN 1279 Standard was also brought to the attention of the group, as well as the fact that most IG manufacturers don't know their own failure rates or cause or have correlated rates from various causes. The support of the sash and system and deflection on failure modes was also referenced as an issue requiring further exploration. There were comments regarding the global utilization of IGUs. It was concluded that a matrix of compatibility of various components along with material compatibility and mechanical stresses that might have an affect on service life failure mode and overall IGU performance should be formed. The P1 test was referenced as a method that accelerates the mode of failure of an IGU unit used as a test protocol for screening, but does not factor in the sash performance. It was suggested that sash details be tested for the worse case sash design, and a tiered system be incorporated to examine the methodologies used in this program. The reference to tools that are appropriate for testing and predicting performance were included in the discussion. It was referenced that the P1 and P2 correlation conditions have been tested and would be an advantage to assist with an understanding of advanced window technologies ("Smart Windows") when the use of special thin films for control of transmission properties is being considered. Also referenced was a performance test program along with the climatological effects on units for simulation techniques, and that simulation stresses can be performed on mathematical models. The panel agreed there is a need to test both IGU and IGU/sash for the worse case conditions for

performance vs. time as a condition to determine overall performance. The climate for the accelerated life testing (ALT) may require additional definition to guide the test program and associated parameters. There was endorsement for needed research to be accomplished that includes other test protocols. The entire panel unanimously accepted this statement.

2. (Item C) Fund independent and other laboratories with in-depth experience with IGU testing to:

a. assess the durability of IG use

b. develop a peer-reviewed plan for predicting service lifetimes

c. implement the plan

The need was established for a basic survey to determine affects of certain products used relative to coatings, grills, muntin bars, and other internal systems regarding the product mix; and that perhaps the Ducker report may give window data on various constructions. It was referenced that a base study be performed for windows and obtain various details relating to unit constructions. It was thought that it is extremely important to examine performance requiring a certain amount of quantification of the product mix relating to performance vs. time of IGUs for predicting service lifetimes. The group unanimously agreed upon this as a major item requiring further research, development, and testing.

3. (Item L) Work in partnership with industry to support, educate, and promote (fund) a study for improving the quality assurance of actual manufacturing processes

a. quality assurance during the manufacturing of IGUs is a significant worldwide issue

It was discussed thoroughly in the group that quality is essential to maintaining performance during long-term IG use. It was referenced that the CEN 1279-6 is a production control document for the CE mark that is established in Europe. It was also referenced that DOE does not need to be involved in the quality assurance (QA) effort; however, QA should be promoted through private industry, associations, certification programs, and other interested parties that can provide the proper methods to achieve quality control referencing the demands of durability. Education about systems and the economic interest of the country were mentioned because of the increasing emphasis on energy conservation, and efficient products requiring specific attention to quality during the manufacturing

process both for initial and long-term performance. It was referenced that a group be provided to work in partnership to support, educate, and promote a study for improving the QA of the actual monitoring and processing of IG units. The group agreed to adopt this as an important item in the concept of durability of seals in IGUs.

> 4. (Item G) Obtain the moisture vapor and permeation (transmission) rates of argon, nitrogen, oxygen, and krypton as a function of temperature for commonly used sealant materials. This is a materials property issue only.

This issue was discussed relating to the database that should be available on the permeability and diffusivity rates of the various sealants as related to the gases used in the gap (airspace) to enhance energy efficiency of the IGU. It was intended for information to be gathered on the sealants and various gases using methods that are available through industry and suppliers for obtaining the international database required.

INTERMEDIATE PRIORITY

> 5. (Item D) Lead aggressively through standards organizations for adapting procedures, practices, methods, and specifications for existing new and advanced window technologies.

The panel agreed that this issue is important because of the continuing effort to improve overall performance from the quality of manufacturing insulating glass units. This is accomplished through standards and specifications that have been in effect, and continue to evolve through the major standards writing groups that are in place and led by industry participation as well as the design profession, suppliers, national laboratories, and users of IGU products.

> 6. (Item F) Continue to fund the deployment of a portable spectrometer or a suitable variance, e.g. the Elmahdy device for the non-destructive, non-evasive determination of the concentration of argon or krypton in field or laboratory tested IG use. Alternatively fund the development of a different type of portable spectrometer or suitable variance e.g. one that is based on spectroscopic such as that used by Cardinal IG. (A unit is needed to monitor the percentage of actual gas fill for production lines.)

It was reviewed by the panel and clearly noted that there is definitely a need to test for argon gas being used extensively in the world market for improved efficiency in insulating glass. The Gasglass unit was referenced as one that may have the

capability of accurately determining the concentration of argon in the 70% and above range, and may also be achieving more accurate results in lower ranges as the product is being developed.

The Insulating Glass Manufacturers Alliance (IGMA) is sorting out patent methods on the device developed by Dr. Elmahdy. It is reported that this instrument obtains results within one percent. An Aerodyne device was referenced as being developed and may be available at a moderate cost to the industry. Concerns relating to the safety and use of each device along with the destructive nature of each unit were briefly discussed within the panel. It was agreed that the device would be useful in implementing recommendations that were offered in Items B and C, which are numbered one and two on the priority list. At present, gas chromatograph, oxygen analyzer, and chamber methods exist for determining argon fill and, it will be beneficial to have an online or offline device providing information in a non-destructive manner for determining the percentage of argon gas fill. The panel agrees that this issue is also important to adopt in the efforts to determine durability of seals.

> 7. (Item H) Fund a scholarly person to work with selected individuals in industry to prepare summaries of knowledge available regarding IG durability, and publish these in peer-reviewed journals, e.g., convert R. Spindler's SIGMA paper (appendix 2 of the resource document) into an ASHRAE paper.

The panel agreed that this would be an important step in providing information and adding credibility to efforts completed in the field of IG durability; the panel subsequently adopted it.

LOWEST PRIORITY

> 8. (Item E) Evaluate the energy-saved vs. consumer costs when using argon instead of air in an IGU.

The panel reviewed information provided by the CEN study, which requires less than one percent per year of loss of argon in an IGU. It was referenced that the sealant system must prove using the standard EN 1279-5 that one percent per year is achieved. It was referenced that argon use for insulating glass may have been oversold in the US market since no non-destructive test methods have been available for argon, and a new method is suggested to review the fill and depletions of argon in an IGU. It was recognized that most sealants would allow depletion, and a benchmark is needed for establishing energy standards along with savings from energy using energy-efficient products. It was also recognized that gas loss is not erratic with regard to IGU design. It was referenced that there are ratings for

code compliance and Energy Star enhancing the use of energy efficient products. It is important to have a way of measuring the percent of argon in a unit that is expected to be available.

> 9. (Item I) Produce simplified visual, video, computer, and/or materials for the consumer on "How to Select" [cost, performance (e.g. air, water, structural, and acoustical) and service lifetime (durability) an energy efficient window for his/her home, perhaps by working through NFRC.

The panel discussion referenced the feasibility of an index about durability and perhaps that some of the study that is being done in NFRC can be adopted and enhanced by information that would be provided to the consumer. It was pointed out that there is information from National Research of Canada relating to the "Sill to Sash" program that may be available for reference as well. Much of the documentation being generated at NFRC does provide information on certain portions of fenestration products and could possibly be enhanced through certain efforts regarding service lifetime, cost, and performance.

> 10. (Item J) Secure the results from computer simulation studies to estimate the affect of gas collapse on the increase in U factors from temperature-induced pressure changes as well as though resulting from the pressure decrease because of the net loss of molecules inside the IGU from out-diffusion of argon.

It was discussed within the panel the issues relating to permeability and provide education on how much dishing at the center of the glass affects the overall U factor of the unit. The influence of performance can be presented in a simplistic or scholarly type manner and it is required that a knowledge base be established and then combine this with Item E which was priority number eight. The affects of the U factor from glass dishing can be obtained from simulated studies using various measurements of the unit and reduce the gap for estimated results related to the U factor. The basics relative to the collapse of the unit and the relation of the diffusion issues, temperature, and barometric pressure can be combined to study the U factor vs. gas collapse effect. This issue was adopted and generally agreed that it could be added to Item E as previously referenced.

> 11. (Item K) Encourage DOE to expedite adoption of the fenestration heating rating (FHR) and fenestration cooling rating (FCR) ratings through NFRC.

DOE could also help by recommending changes in building codes. The discussion related to this topic was centered on considering the window as an appliance. DOE

has encouraged expediting the use of Energy Star as a program to enhance energy efficiency. It was mentioned that the FHR and FCR provide the basis for the long-term energy performance program at NFRC, and the adoption of these items would affect the overall understanding of the window (fenestration) system as an energy product to the end-user.

The panel also evaluated Item M, which was to evaluate a unique, non-conventional reverse dual-seal design. It is reported that this design greatly reduces the durability issues compared to the conventional seal design used by most IGU manufacturers, and should be analyzed to the predicted service lifetimes of the two types of designs. It was felt that this item was a subset of other recommendations, as alternate edge seal technologies will be reviewed with regard to overall performance of seal durability. The seal technologies that may improve the durability with regard to several conventional designs used by the majority of IG manufacturers will be compared when the overall predicted lifetimes of the various types of product designs are evaluated.

The panel devoted time to estimate the amount of time and funding that would be required for each of the major items. The following list of one through eleven of the previously referenced items in priority is listed below for reference. The items are budgeted only with regard to a rough estimate provided by the panel in an effort to grasp an overall amount of time and funding that may be required to accomplish the tasks listed.

1. Item B, three years - $2,000,000
2. Item C, five years - $2,000,000
3. Item D, four to eight years - $200,000
4. Item E, three years - $20,000
5. Item F, three years - $20,000
6. Item G, three years - $20,000
7. Item H, three years - $100,000
8. Item I, three years - $50,000
9. Item J, three years - $30,000
10. Item K, three years - $30,000

11. Item L, three years - $50,000

The rough budget estimate was used to obtain an amount for each of the three categories for the High, Intermediate, and Low priorities. Hopefully, the amount of finances may be available through DOE that can fund the effort.

Sam Taylor recommended that guidance on the three high priority items B, C, and L be reviewed closely by a small task group. A statement of work for Items B, C, and the timelines were requested, and a report for recommendations for each of these work items will be processed for further study.

Finally, it was recommended that a small group be assembled to develop a work statement, to begin work on a flow chart on the starting points with regard to the project requirements, and that the task group undertakes the effort to continue this work. Volunteers for the task group were Bob Spindler, Bill Lingnell, Hakim Elmahdy, and Carl Wagus. Werner Lichtenberger, Andre Piers, and Jim Fairman also indicated an interest in working with the task group. It was suggested that the group meet on Friday, August 17 prior to the IGMA meeting in Canada to continue the efforts and review the tasks B and C for reference to additional guidance relating to a logical approach to achieving the recommendation for these work items.

It is intended that a follow-up report relating to the efforts will be submitted to summarize the results from the meeting in LaMalbaie, Quebec, Canada.

Respectfully submitted,

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Consultant